REMARKS

Applicants thank the Examiner for the thorough consideration given the present application. Claims 4-21 and 26-28 remain under consideration. Claims 22-25 have been withdrawn from consideration. The Examiner is respectfully requested to reconsider his rejections in view of the amendments and remarks as set forth below.

Rejection under 35 U.S.C. 112

Claims 26-28 stand rejected under 35 U.S.C. 112, 2nd paragraph as being indefinite. This rejection is respectfully traversed.

The Examiner objected to the language in the final paragraph of each of these three independent claims and indicated that the impurity pairs will affect the layer rather than the materials. By way of the present amendment, Applicants have removed the previous language. The language which has been added now refers to changes in the layer rather than in the materials as suggested by the Examiner. Accordingly, this rejection is believed to be overcome.

Rejection under 35 U.S.C. 103

Claims 4-21 and 26-28 stand rejected under 35 U.S.C. 103 as being obvious over Nishizawa et al. (USP 5,693,139) in view of

Edmond et al. (USP 5,739,554). This rejection is respectfully traversed.

The Examiner cited the Nishizawa et al. reference to show the general idea of layers of gallium and arsenic and where impurities can be introduced in alternate layers. The Examiner admits that Nishizawa et al. does not disclose that the times for supplying the impurities are close to each other.

The Examiner cited the Edmond et al. reference to show a gallium nitride layer co-doped with both a group II acceptor and a group IV donor. The Examiner feels it would have been obvious to one of ordinary skill in the art to modify the Nishizawa et al. reference with the teachings of Edmond et al. in order to form a co-doped GaN layer. However, the Examiner also admits that this combination is silent in terms of forming impurity pairs within the crystal raw materials. However, the Examiner feels that the forming of the impurity pairs would be inherent since the references teach similar supplying of materials.

Applicants submit that the present claims would not be obvious over this combination of references. Independent claims 26-28 have now been amended to specifically recite the formation of the pairs as a step in the process rather than merely as a wherein clause.

Thus, this statement now is stronger in terms of the formation of the pairs being an actual step of the process. In addition, the results of this formation of pairs is also stated in these claims. In particular, the claim states that the formation of the pairs results in the decrease of activation energy and increase in carrier concentration. These statements are based on statements in the specification on page 22, lines 11 and 13.

Neither of the references nor their combination teach the concept of the lowering of this activation energy or the increase in the carrier concentration. Since the references do not discuss the concept of the formation of impurity pairs, they could not have foreseen this result and accordingly, these claims are believed to be additionally allowable. In view of this, Applicants submit that claims 26-28 are each allowable over this combination of references.

Claims 26-28 now also point out that the impurity pairs form a donor-acceptor complex and that this process uses co-doping. Co-doping is a doping method based on a theory by which an acceptor level can be reduced by creating a complex made of two acceptors and one donor in a crystal. However, this theory has not been successfully accomplished in the past. Typically, the donor and

acceptor are supplied into the crystal in a scattered manner (or out of order) and the probability of creating a complex is quite low so that the donor and acceptor effects tend to damp each other.

On other hand, the present inventors have found out that atoms move very actively on a crystal surface when the donor and acceptor are supplied in a certain sequence by using an atomic layer growth and have discovered that a donor-acceptor complex is readily achieved in this process. The inventors have succeeded in achieving GaN having a hole concentration in the range of 10^{19} by this method, which no one previously has accomplished and also has succeeded in achieving a hole concentration of 5×10^{18} which has not been accomplished even in AlGaN.

This principle of the present invention is based on the fact that the donor and acceptor can move easily on the crystal surface and readily make the complex. This concept is not related to the teachings of Nishizawa et al. and Edmond et al. as suggested by the Examiner, and has never even been suggested therein.

Nishizawa et al. focuses on the fact that a semiconductor becomes p-type or n-type by performing doping of one kind of the atom via an atomic layer growth of alternate supply. Although the semiconductor of the p-type or n-type is naturally created, only an

acceptor level or a donor level of a deep level is created in a semiconductor having a deep band gap like GaN. Thus, the method is not useful for forming a highly concentrated p-type layer of a wide band semiconductor having a large band gap.

The present invention efficiently creates a complex of the donor and acceptor by supplying two kinds of atoms into a same atomic layer or supplying the two kinds of atoms into adjacent atomic layers in a manner not even imagined by others. Thus, the present inventors have discovered that atoms have the behavior of moving very actively on the crystal surface and that co-doping can be achieved using this behavior and have demonstrated this theory in the present invention.

Concerning the Edmond et al. reference, the concept of co-doping is described therein. However, although several pieces of complex would be created when a large amount of donor and acceptor are simultaneously supplied, crystallinity deteriorates and the hole concentration rather reduces generally due to the compensation effect of the donor and acceptor. Edmond et al. does not disclose how to solve the problem of achieving co-doping at all, but on the contrary this is only achieved using the present invention. Accordingly, Applicants submit that these concepts are not seen in

the references and that independent claims 21 and 26-28 define thereover.

Claims 4-20 depend from these allowable independent claims and as such are also considered to be allowable. In addition, each of these claims includes additional limitations. Thus, claims 4 and 5 include limitations related to the times of supplying the materials. Claims 6-10 discuss the particular materials utilized. Claims 11-20 point out that the impurity materials are p-type and n-type material. Accordingly, these claims are believed to be additionally allowable.

Claim 21 is an independent claim which describes the four steps of supplying materials. This claim has now been amended to point out that the impurity pairs are formed during the first two steps and that the activation energy is decreased and the carrier concentration is increased as a result. Accordingly, Applicants submit that this claim is allowable for the same reason recited above in regard to claims 26-28.

Claim 21 was further rejected as being obvious over Nishizawa et al. in view of Edmond et al. and further in view Manabe et al. The Examiner cited the Manabe reference to show the supplying of TESi. However, even if this reference does teach this type of

material, the combination of the three references still does not teach the formation of the impurity pairs and the resultant decrease in energy and increase in concentration. Accordingly, Applicants submit that claim 21 is allowable over this three-way combination of references.

Conclusion

In view of the above remarks, it is believed that the claims clearly distinguish over the patents relied upon by the Examiner, either alone or in combination. In view of this, reconsideration of the rejections and allowance of all the claims are respectfully requested.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Robert F. Gnuse (Reg. No. 27,295) at the telephone number of the undersigned below, to conduct an interview in an effort to expedite prosecution in connection with the present application.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees

required under 37 C.F.R. §§ 1.16 or 1.17; particularly, extension of time fees.

Respectfully submitted,

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